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# A Novel Algorithm for Rotated Human Face Detection

Xiao-guang Lv  Jie Zhou  Chang-shui Zhang

Department of Automation, Tsinghua University
Beijing 100084, P.R.China

## Abstract

*In this paper we present a framework to detect human faces rotated within the image plane. A novel orientation histogram of an image is constructed using local orientation analysis. From the view of oriented pattern, the histogram of human face shows the symmetry with respect to the orientation $\beta$ of the principal axis, also a local peak occurs at the orientation orthogonal to $\beta$. We analyze the histogram to find the orientation of the face principal axis, with which the conventional upright face detectors can be used to verify the supposed rotated face. Experimental results show that the algorithm is effective.*

## 1. Introduction

Human face recognition has attracted considerable attention in recent years [1]. In an automatic human face recognition system, face detection is the first stage, also quite important to the performance of the following stages and the whole system. The aim of face detection is to obtain the common characteristics of human faces and to distinguish between two kinds of patterns—human face pattern and non-human face pattern.

Many techniques have been applied to face detection work, such as correlation templates [2], hierarchical knowledge-based approach [3], neural network [4]. Although the existing face systems can give well performance in detection of upright frontal faces, locating rotated face is still a difficult problem. This problem has received attention in the literature [5].

To generalize the detection systems for upright faces to at any degree of rotation in the image plane, two ways can be tried:

One is to rotate the image by a small degree, which is in the system's range of rotation tolerance, step by step up to 360 degree, then use the original system to detect faces in each of the rotated images. However, it would be a computationally expensive task. For example, if the original system is invariant to 10 degree of rotation from upright, the entire detection procedure need to be applied at least 18 times to each image.

Our framework is a much faster one. Suppose a window under consideration contains a face. Using a novel statistical orientation feature, we find the rotation angle of supposed face image. Then turn the supposed face image upright. Applying the upright face detection system to detect the "derotated" window and verify it. It should be mentioned that because a window contains no face will contain no face after rotation, this framework can not result in any additional false detection.

Orientation analysis is introduced in the next section. In Section 3, we analyze the orientation characteristics in the human face and present the method to search for the rotation angle of face image. The experiments and discussion are provided in Section 4. Conclusions are given in the Section 5.

## 2. Analyzing Orientation and Symmetry

### 2.1 Local Orientation Analysis

It has been demonstrated [6,7] that for a strongly oriented intensity pattern along one direction, the power spectrum of such a pattern clusters along a line through the origin in Fourier transformation domain and the direction of the line is perpendicular to the dominant spatial orientation. In stead of the actual computation in the Fourier transformation domain, the orientation map $\theta(x,y)$ and anisotropic strength map $g(x,y)$ can be calculated directly from intensity image $I(x,y)$ and its first order partial derivatives, by:

$$\theta(x,y)=\frac{1}{2}\tan^{-1}\frac{\iint_{\Omega}2I_xI_y\,dxdy}{\iint_{\Omega}(I_x^2-I_y^2)\,dxdy}+\frac{\pi}{2} \qquad ...(1)$$

$$g(x,y)=\frac{(\iint_{\Omega}(I_x^2-I_y^2)\,dxdy)^2+(\iint_{\Omega}2I_xI_y\,dxdy)^2}{(\iint_{\Omega}(I_x^2+I_y^2)\,dxdy)^2} \qquad ...(2)$$

In the above equations, $\Omega$ is a small neighborhood of